Technical Paper 285

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TRAINING TRANSFER FROM MINI-TANK RANGE TO TANK MAIN GUN FIRING

Robert W. Bauer

ARI FIELD UNIT FORT KNOX

U. S. Army
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Subcaliber training devices are used for preliminary firing exercises to reduce ammunition costs during tank gunnery training. The mini-tank range has been recently introduced into US Army armor training after extended use by the British army. The present report compares the effectiveness of two training devices, the mini-tank range and the tank coaxial machine gun, in terms of gunner's qualifying performance with the tank main gun.

The training transferred from the mini-tank range experience to 105-mm main gun live firing was relatively effective. The mini-tank range exercises were

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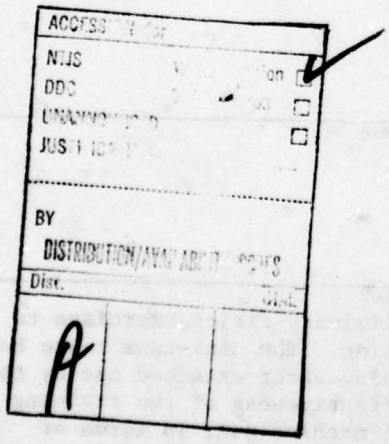
in general more accurate and efficient and less costly than the 7.62 mm coaxial machine gun in single shot mode used for comparison.



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Combat Unit Training

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FOREWORD

The research reported here is part of a broader program on combat unit training and simulation being conducted by the US Army Research Institute for the Behavioral and Social Sciences (ARI) in both the ARI field units and the Unit Training and Evaluation Systems Technical Area.

The ARI Field Unit at Fort Knox, KY, is charged with developing cost-effective methods for collective tank training. The field unit has the objective of improving effectiveness and efficiency of training armor crews by analysis and field research on transfer of training from the training device simulations to actual performance.

Small caliber training devices can be used for the preliminary tables in tank main gun exercises. The present research evaluated the effectiveness of current subcaliber training compared to training with the .22-caliber mini-tank range device, which provided a savings in operating cost.

Research was done by personnel of the Fort Knox Field Unit during armor exercises at Fort Hood, TX.

ARI wishes to express appreciation for the support and cooperation of COL John P. Prillaman, Commander of the 2d Brigade, 1st Cavalry Division, Fort Hood; and special thanks to the officers and men of 1/7 Cavalry, commanded by LTC John E. Toye. The entire program is done under Army Project 2Q763743A773 and is responsive to requirements of the US Army Armor School at Fort Knox; the Army Training and Doctrine Command; and the Army Forces Command.

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TRAINING TRANSFER FROM MINI-TANK RANGE TO TANK MAIN GUN FIRING

BRIEF

Requirement:

The mini-tank range, a device recently introduced into US Army armor training after extended use in the British Army, previously has not been evaluated for training effectiveness. The purpose of this research was to compare the training effectiveness of the new device with current subcaliber training using the tank coaxial machine gun. The research was in terms of transfer of training from the subcaliber devices to main gun firing performance and of relative training efficiency and cost.

Procedure:

In coordination with a battalion gunnery exercise at Fort Hood, TX, 105 mm M60A1 main gun firing performance was compared among three tank company groups of approximately equal experience. Two experimental groups (N = 17 and 15) fired the .22 caliber mini-tank range device tables as preliminary exercises to Table IV main gun. The control group (N = 18) used the 7.62 mm coaxial machine gun (single shot) preliminary tables. Each of the three groups had 15 or more tank performances measured by independent evaluation teams of subcaliber Table II and main gun Tables IV, V, and VIII. The control group and one experimental group fired 130 rounds per man on the preliminary tables; the second experimental group fired 260 rounds, the full number prescribed for mini-tank range tables (TC 17-12-6).

Findings:

The mini-tank range exercises were in general more accurate and efficient and less costly than those using the 7.62 mm subcaliber training device (TC 17-12-5). The experimental group given the full firing experience on the mini-tank range had faster first-round time-to-fire scores on main gun Table IV, achieved the best main gun hit performance on Tables IV and VIII, and also achieved the best overall scores and had no crew failures on Table VIII. However, differences among the three groups on main gun performance measures were generally not statistically significant. Individual experience showed no significant relationship with criterion main gun performance.

Utilization of Findings:

Results and recommendations will be used by US Army Armor School and US Army Training and Doctrine Command in armor training development and by US Army Forces Command units in planning and administering tank gunnery training.

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OBJECTIVES

In the training of armor crewmen, use of fuel and costs of ammunition are matters of much concern. Use of full field equipment is so expensive that numerous simulator and subcaliber training devices have been developed or adopted by the armor community in an effort to cut costs and yet provide good gunnery training. The field mini-tank range is a subcaliber training device, usually associated with a training complex. The device has a long history of use in the British Army and has shown a high potential for cost-effective application to US armor training. Even though the mini-tank range has been put into regular training use by some units, effectiveness of such training has not yet been systematically evaluated.

Training effectiveness can best be evaluated by measurement of transfer of training from the device exercise to some criterion performance with full field equipment.

In this case, training using the device is intended to provide skills necesssary to effective main gun crew performance, especially gunner performance. The ultimate criterion for armor crewmen is, of course, combat effectiveness.

For obvious reasons, however, the performance chosen for use as a research criterion measure must be some more accessible training exercise calling upon a representative array of combat gunnery skills. The main gun exercises making up the gunnery tables could provide criterion measures, especially Gunnery Table VIII, the crew qualification exercise.

A training transfer evaluation design was developed in coordination with planning for a battalion's tank gunnery range training exercises.

The coordination provided advantages in the conservation of fuel, maintenance, and main gun ammunition (already allocated to the battalion for training), while making available the battalion resources for division into comparable controlled training groups.

The primary purpose of the experiment was to evaluate transfer of mini-tank range training to live 105 mm main gun firing performance of tank crew members. The plan called for a comparison of a mini-tank range trained group with a group trained on the standard 7.62 mm tables (TC 17-12-5).[1]

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[1] US Army Armor School, Tank Gunnery Training. TC 17-12-5, Fort Knox, KY, January 1975.

Other purposes included gaining understanding of the relationships among gunnery exercises, improving administration of preliminary gunnery exercises (see Appendix A), and the early prediction of more effective gunner performance (see Appendix B).

METHOD

DESIGN AND PROCEDURES

The research design involved a comparison among three company-size groups: a control group using the current training method and two experimental groups using two levels of training on the mini-tank range prior to criterion performance on the main gun.

The control group of 18 tank gunners used 7.62 mm ammunition in the coaxial machine gun (single shot) on the preliminary tables as provided in TC 17-12-5.

The two experimental groups used .22 caliber long rifle ammunition in the subcaliber training device on the mini-tank range in preliminary tables as described in TC 17-12-6.[2] The control group followed TC 17-12-5 through the preliminary Gunnery Tables I, II and III, each man firing 130 rounds.

The experimental groups, X_1 and X_2, required each man to fire 130 rounds and 260 rounds, respectively, on Gunnery Tables I through VII on the mini-tank range. (258 rounds are prescribed for Gunnery Tables I through VIII on the mini-tank range in TC 17-12-6.)

This requirement matched experimental group X_1 with control group C on preliminary subcaliber rounds and also provided data on experimental group X_2 which was given the full mini-tank range experience through Table VII. (See Table 1.)

The mini-tank range exercises were conducted as part of a set of training exercises that included a tank crew qualification course (TCQC), a ranging and tracking course, and a synchronization and alignment exercise. All three groups completed all the exercises except the mini-tank range exercises, which were given only to the two experimental groups.

During the TCQC, an assistant instructor (AI) rode on each tank; during the mini-tank range exercises an officer or noncommissioned officer often served as AI, sometimes serving as observer or loader while directing the sequence of training (Figure 1).

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[2] US Army Armor School, Field Mini-Tank Range Complex. TC 17-12-6 DRAFT, Fort Knox, KY, August 1975.

The criteria for comparison of relative transfer of training were to be gunner performances on main gun on Gunnery Tables IV, V, and VIII, as scored by evaluation teams drawn from resources other than the battalion under study.

Table 1

RESEARCH DESIGN

	Company Groups		
	Control Group (C)	Experimental Group 1 (X_1)	Experimental Group 2 (X_2)
n (tank/gunners)	18	17	15
Preliminary tables	I,II,III 7.62 mm (TC 17-25-5)	I,II,III,IV, V,VI,VII Mini-tank range (TC 17-12-6)	I,II,III,IV V,VI,VII Mini-tank range (TC 17-12-6)
Preliminary tables total number rounds per man (day & night)	130	130	260
Tank Crew Qualification Course (TCQC) (dry)	x	x	x
Main gun tables (all TC 17-12-5)			
Zero	x	x	x
IV (day only)	x	x	x
V (day only)	x	x	x
VIII (day & night)	x	x	x

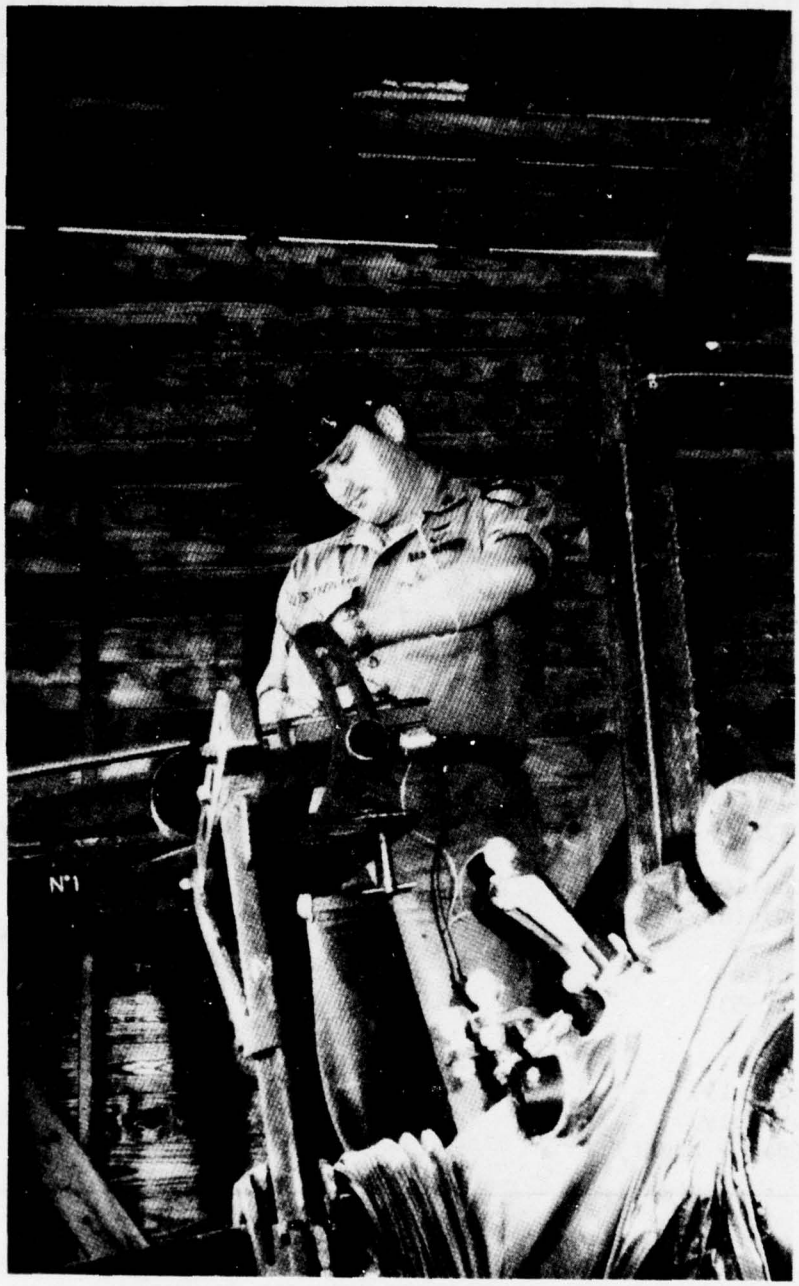

Figure 1. Officer serving as instructor while loading .22 caliber subcaliber training device (SCTD)

SUBJECTS

The subjects were the gunners of one armored cavalry battalion, which was completing its annual tank gunnery training and crew qualification cycle at Fort Hood, TX. Gunner performances could be observed and measured as the gunners performed the preliminary subcaliber tables and the main gun exercises culminating in Table VIII.

The battalion required that crews proceed through the exercises in company groups, maintaining company integrity throughout the training, except that the battalion headquarters tank crews were added to one company during the firing exercises.

The requirement to maintain company integrity limited the number of comparison groups to a maximum of three and did not permit experimental control of crew assignments. It is widely assumed that tank crew experience contributes to proficiency.

Therefore, data on gunner experience were gathered across groups in order to permit an assessment of group comparability. Four experience measures on gunners were obtained (Table 2). The first was simply months of experience in MOS 11E (Armor Crewman).

The second was months of experience in the tank commander position. The third was months of experience in the gunner position. The fourth measure was a count of gunners who had qualified during the prior three years.

Table 2

COMPARISON OF SUBJECT EXPERIENCE ACROSS GROUPS

	Company Groups		
Group	Control Group[a] (C)	Experimental Group 1 (X_1)	Experimental Group 2 (X_2)
n (tanks/gunners)	18	17	15
Months of experience[b]			
in MOS 11E	0-16-96	0-15-60	11-33-63
as Tank Cmdr	0-0-6	0-0-24	0-0-24
as Gunner	0-4-70	0-6-40	0-3-24
Gunners qualified prior 3 yrs	4	5	5

[a] Included battalion headquarters crews.
[b] Months of experience are shown as minimum-median-maximum.

Though the X_2 group appeared to have more experience in the MOS and the X_1 group more experience as gunners, the three groups were regarded as equivalent and comparable for the purpose of the experiment.

Correlation/coefficients run after the data were gathered indicated no significant relationship between MOS 11E experience and Gunnery Table VIII scores ($r = -.005$, $n = 41$), and no significant relationship between gunner assignment experience and Gunnery Table VIII scores ($r = -.05$, $n = 40$).

Prior agreement with the battalion that no gunners were to be changed from their original crew assignment prior to completion of Gunnery Table V main gun firing permitted the use of Gunnery Tables IV and V as intermediate criteria of tank gunner performance. Relatively few gunners were actually changed through the entire sequence.

CRITERIA

Measures of interest in the transfer experiment were gunner performances on the tank main gun Tables IV, V, and VIII, as scored by independent evaluation teams. (Machine-gun scores from preliminary tables were not included in the statistical comparisons.)

The maintenance of crew stability through Gunnery Table V permitted the use of daytime main gun performance on Gunnery Tables IV and V as intermediate criteria. In actuality, crew changes were rather few even after completion of Gunnery Table V.

It was possible to track most of the gunners through the qualification Gunnery Table VIII, which served as the final criterion. On earlier tables, only day firing scores were analyzed, but on Gunnery Table VIII both day and night scores were recorded and analyzed, with machine-gun exercises separated out as noted above.

Table VI, a machine-gun table, was not included in the analysis, and Gunnery Table VII, a practice for Table VIII, was not scored by an independent team and so was not included.

On Gunnery Tables IV and V, hits were scored as well as time-to-fire first round (in seconds) on each engagement. On Table VIII, hit scores and time scores were recorded but actual time-to-fire was not.

In combat gunnery, it is important not only to get a high percentage of hits, but also very important to get at least one hit in each engagement. Thus, a score was derived for each main gun table to indicate the percentage of engagements in which at least one hit was obtained.

FIELD PROCEDURES

The BC scope was used from the range tower in scoring main gun tables. Generally, members of the tank crew received a quick report on their hits after each engagement on main gun tables. A timer mounted on each firing tank also recorded time-to-fire first rounds on Tables IV and V main gun.

In order to get equivalent times-to-fire, each gunner was instructed to lay the main gun off targets and on the pole marking the edge of the range fan prior to each engagement.

Then the timing of the first round was begun either with the first movement of the gun or the tank commander's fire command, with the word, "Gunner", whichever was first observed by the timer. Elapsed time closed with the report of the gun.

The early plans were to use Table II, a burst-on-target (BOT) adjustment table in both TC 17-12-5 and TC 17-12-6, as a preliminary control and for comparison among all three groups.

Differences between the 7.62 mm machine gun simulation and the .22 caliber mini-tank range simulation interacted with the firing results obtained and made such a controlled comparison impossible. On the 7.62 mm range, the targets for Gunnery Tables I, II, and III were made up of concentric 4-inch and 8-inch circles at 60 meters (m) range.

The smaller, 4-inch circle subsumed 2.2 mils at that range. Because this size was more nearly comparable to the 1.8 mils subsumed by the mini-tank range Gunnery Table II targets, second-round hits on the smaller target were selected for comparison in the analysis.

The hit percentage for the control group was relatively low in comparison with the two experimental groups, despite the somewhat larger target size.

The control group officers had great difficulty in achieving convergence of the coaxial machine gun at 60 m versus the design convergence at 800 m. Figure 2 illustrates the shimming necessary to force the gun to the extreme right of the aperture ring.[3]

Largely because of this problem, the control group used all the first day and part of the second day on the range on Gunnery Table I, which required zeroing the 7.62 mm machine gun at 60 m, thus consuming a major portion of the three days assigned to that group for Gunnery Tables I, II, and III and reducing the time remaining for the bulk of the preliminary table firing.

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[3] Tank Gunnery Assistance Team, 1st Cavalry Division, Fort Hood, TX, advised on review that such shimming should not be done--that procedures described in operator's manual, TM 9-2350-215-10, make convergence at 60 m easier.

The control group of commissioned and noncommissioned officers also felt that the zero shot pattern of the 7.62 mm machine gun was very large at 60 m and unsuitable for a BOT exercise. They expressed the opinion that single-shot fire of the coaxial machine gun puts unusual wear on the breech block, bolt assembly, and the extractors.

Figure 2. Shimming necessary to force convergence on sight at 60 m

The mini-tank range .22 caliber simulation used a range in which the nearest targets are at about 1000 m simulated by an actual range of 53 feet near the front edge of the sand table.

From that line on, each foot represents 100 m; 1200 m (the zero-range) is thus represented by 55 feet, and 4000 m or maximum range by 83 feet, as measured from a stake at the front wheel of the tank.

Though the targets used for Gunnery Tables I and II were slightly smaller in angular area than the targets used on the 7.62 mm range, about twice as many second-round hits were achieved on the mini-tank range Table II (see Table 3). Presumably, this result was a function of the greater accuracy of the .22 caliber system.

Table 3

PERCENTAGE OF HITS AFTER BOT, TABLE II

	Company Groups		
	Control Group (C)	Experimental Group 1 (X_1)	Experimental Group 2 (X_2)
All crewmen	39	50	70
Gunners only	37	75	85

The three groups did not fire exactly the same number of main gun rounds on each table, as is indicated in Table 4. One company did not fire second rounds after first-round hits on Table IV. On Table VIII, gunners who achieved more first-round hits generally used fewer rounds and received more credits for rounds saved.

Table 4

MEAN NUMBER OF ROUNDS FIRED PER GUNNER

	Company Groups		
	Control Group (C)	Experimental Group 1 (X_1)	Experimental Group 2 (X_2)
Subcaliber Tables			
I, II, III (TC 17-12-5)	(7.62 mm) Total 130	(.22 cal) None	(.22 cal) None
I through VII (TC 17-12-6)	None	Total 130	Total 260
Main Gun Tables			
Zero	5+	5+	5+
Table IV (day)	18	16	18
Table V (day)	14	14	14
Table VIII (day and night)	14	15	14

RESULTS

TRANSFER OF TRAINING

Main gun Tables IV and V were analyzed in terms of time-to-fire first round of each engagement and target hits on each engagement. The mean time-to-fire first round is presented in Table 5.

Groups trained on the mini-tank range achieved better time scores than the control group on Gunnery Table IV but not on Table V.

Analysis of variance indicated that the differences were statistically significant between Groups ($F(2,42) = 5.78$, $p < .01$), Tables ($F(1,42) = 10.50$, $p < .005$), and the Groups by Tables Interaction ($F(2,42 = 9.74$, $p < .001$).[4] Analysis of variance summary tables are in Appendix C.

Table 5 shows the percentage of engagements meeting a time criterion of $\leq$ 10 seconds for battlesight engagements or $\leq$ 15 seconds for precision engagements. Time limits for battlesight firing are generally shorter because the round is preloaded and the range is previously indexed, thus reducing the time required to fire the first round.

Analysis of variance indicated significant differences for Groups ($F(2,42) = 4.63$, $p < .05$) and groups by Tables Interaction ($F(2,42) = 9.48$, $p < .001$) but not for Tables ($F(1,42) = 3.42$, $p > .05$). (See Appendix C for summary tables.)

Target hit results on main gun Tables IV and V are shown in Table 6. The X_2 group showed the best hit performance on Table IV but the three groups performed equally well on Table V, the moving target table. The differences between the groups were not significant, however.

Analysis of variance with unweighted means solution showed a significant difference between Tables, $F(1,46) = 27.21$, $p < .001$, but no significant differences among Companies (groups) and no significant interaction ($F(2,46 = .46$, $p > .05$, and $F(2,46) - 2.64$, $p > .05$, respectively. (See Appendix C for summary tables.)

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[4] Kirk, R. E. Experimental Design: Procedures for the Behavioral Sciences. Belmont, CA: Brooks/Cole, 1968.

Table 5

MEAN TIME-TO-FIRE FIRST ROUND OF ENGAGEMENTS FOR ALL GUNNERS, TABLES IV AND V

	Company Groups		
	Control Group (C)	Experimental Group 1 (X_1)	Experimental Group 2 (X_2)
TABLE IV			
Mean time-to-fire	14 sec.	11 sec.	9 sec.
Percent meeting criteria[a]	65%	80%	96%
TABLE V			
Mean time-to-fire	10 sec.	11 sec	9 sec.
Percent meeting criteria[a]	88%	82%	88%

[a] Percent of engagements meeting time criteria of $\leq$ 10 seconds on battlesight engagements, $\leq$ 15 seconds on precision engagements.

Table 6

MEAN TARGET HIT PERCENTAGES FOR GUNNERS, TABLES IV AND V

	Company Groups		
	Control Group (C)	Experimental Group 1 (X_1)	Experimental Group 2 (X_2)
Table IV	33%	29%	44%
Table V	58%	58%	54%

Table 7 summarizes the results on main gun Table VIII. For purposes of comparison, the main gun scores were transformed into percentages of the maximum score possible for each gunner on day and night firing combined.

The mean score for the X_2 group was highest, but the differences among groups were not statistically significant. The groups were also examined for differences in crew failures and for differences in their median level of qualification, two measures important to commanders.

The X_2 group had no crew failures. The X_1 group, which had fired half the number of rounds prescribed on the mini-tank range tables, performed poorly on Table VIII, with five failures.

The X_2 average (median) performance on Table VIII was Distinguished the highest level of qualification, while the X_1 and C groups average performance was Expert. Analysis of variance indicated a nonsignificant mean score percent, $F(2,40) = .49$, $p > .05$.[5] (See Appendix C.)

Table 8 shows, for each group, the percentage of total engagements in which one or more hits were scored. This measure, devised for the present analysis, appears to have face validity as a criterion approaching combat requirements.

The differences shown favored the X_2 group on Gunnery Tables IV and VIII, but the differences between groups were not statistically significant.

Analysis of variance with unweighted means solution was significant for Tables, $F(2,76) = 19.40$, $p < .001$; nonsignificant for Groups, $F(2,38) = .52$, $p > .05$, and Interaction, $F(4,76) = .10$, $p > .05$. (See Appendix C.)

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[5] Bruning J. L., and Kintz, B. L. Computational Handbook of Statistics. Glenview, Illinois: Scott, Foresman, 1968.

Table 7

MEAN SCORES, CALCULATED AS PERCENT OF MAXIMUM POSSIBLE SCORES, AND NUMBER OF CREW FAILURES, TABLE VIII

	Company Groups		
	Control Group (C)	Experimental Group 1 (X_1)	Experimental Group 2 (X_2)
Mean score	74%	67%	80%
Crew failures	2	5	0

Table 8

PERCENTAGE OF ENGAGEMENTS IN WHICH AT LEAST ONE HIT WAS SCORED

	Company Groups		
	Control Group (C)	Experimental Group 1 (X_1)	Experimental Group 2 (X_2)
Table IV	53%	50%	63%
Table V	69%	71%	64%
Table VIII	81%	75%	83%

EFFICIENCY OF TRAINING

Observers reported that the mini-tank range was set up and training begun in a half-day or less with each of the two experimental companies. The control group required more than a day to begin training on the 7.62 mm range largely because of the extreme difficulty in achieving convergence with the coaxial machine gun at 60 m.

Control group efficiency was also reduced by problems in the reliability of the 7.62 mm machine gun. Furthermore, control group scores on Gunnery Table II were reduced by the wide dispersion and relatively inaccurate performance of the 7.62 mm machine gun in the single-shot point target mode.

The mini-tank range also presented some difficulties in set-up; most notable was the failure to insert the aperture disc to eliminate parallax in the sight picture prior to firing.

Much of the X_1 group Table II firing had been completed before a sight parallax problem was resolved by the proper insertion of the disc aperture into the sight assembly. This problem did not adversely affect the X_2 group, which followed the X_1 group on the mini-tank range.

Recommendations toward the more efficient operation of the mini-tank range and suggestions for improvement of TC 17-12-6 are included in Appendix A.

However, observation of this battalion indicated that the 258 rounds prescribed in TC 17-12-6 for eight preliminary tables, when fired in an effective training sequence, will ordinarily require less time on the range than the 130 rounds of 7.62 mm prescribed for the three preliminary Tables of TC 17-12-5.

Ordinarily a tank company commander would plan to give all his tank commanders, tank gunners, and potential or alternate tank gunners the full mini-tank range training prior to the main gun tables. In effect, 60-80% of the company tank crewmen can be expected to complete the mini-tank range tables in about three days and evenings of concentrated exercises.

COSTS

The most recently constructed mini-tank range at Fort Hood is a two-tank range built by the 2nd Armored Division in 1974 at a cost of $16,000 for material and $7,000 for troop labor. These costs do not apply to the entire complex but to the mini-tank range, exclusively.

However, these costs do include targets, moving target system, electrical system, target sand table, retaining walls, earth-moving, and covered firing station. Allowing 20% additional for inflation since 1974, the cost of a mini-tank range complex was estimated at $27,600 (1976 dollars).

In comparison with firing subcaliber tables on the more remote field ranges, there are substantial savings in fuel, travel, and cleanup time in the use of the more accessible mini-tank ranges on post.

The savings in ammunition alone are very significant and nearly constant from one post to another. For example, a battalion with 50 tanks firing on Gunnery Tables I, II, III on the 7.62 mm range will require 130 rounds per man or 26,000 rounds for all crew members to fire on TC 17-12-5.

At 20 cents per round, the cost of ammunition is $5,200 for the 7.62 mm range only. On the mini-tank range, using Table I through VIII from TC 17-12-6, each man will fire twice as many rounds in the same allotted time on the range. These 260 rounds per man will require 52,000 .22-caliber long rifle rounds at one cent per round, or $520.

One battalion firing the exercises quarterly at the indicated ammunition cost saving of $4,680 each quarter would amortize the total capital investment in the mini-tank range construction in less than 18 months (Figure 3).

DISCUSSION

In any such field experiment, a number of extraneous and uncontrolled variables interact with the results obtained.

Certainly, good management and troop morale can affect the quality of performance of a tank company, regardless of the training procedures employed. Equipment failures and bad weather can plague the best efforts of men with machines. Weather differences were not significant during the experiment.

However, there were equipment maintenance and operational problems with both old and new tanks in the battalion. The exchange of the older M60A1 tanks for new M60A1/AOS tanks (with add-on stabilization) was occurring throughout the battalion.

All three groups were receiving the new tanks just prior to the gunner exercises; C group inluded 10 AOS among their 18 tanks, X_1 group included 9 among their 17, and X_2 group had 14 among their 15.

These differences should be interpreted as of no special advantage to any particular group, since the new AOS tanks were by no means trouble-free and no firing was done "on the move."

An improvement is generally expected from one training experience to the next. However, it is surprisingly difficult to demonstrate such relationships among gunnery exercises.

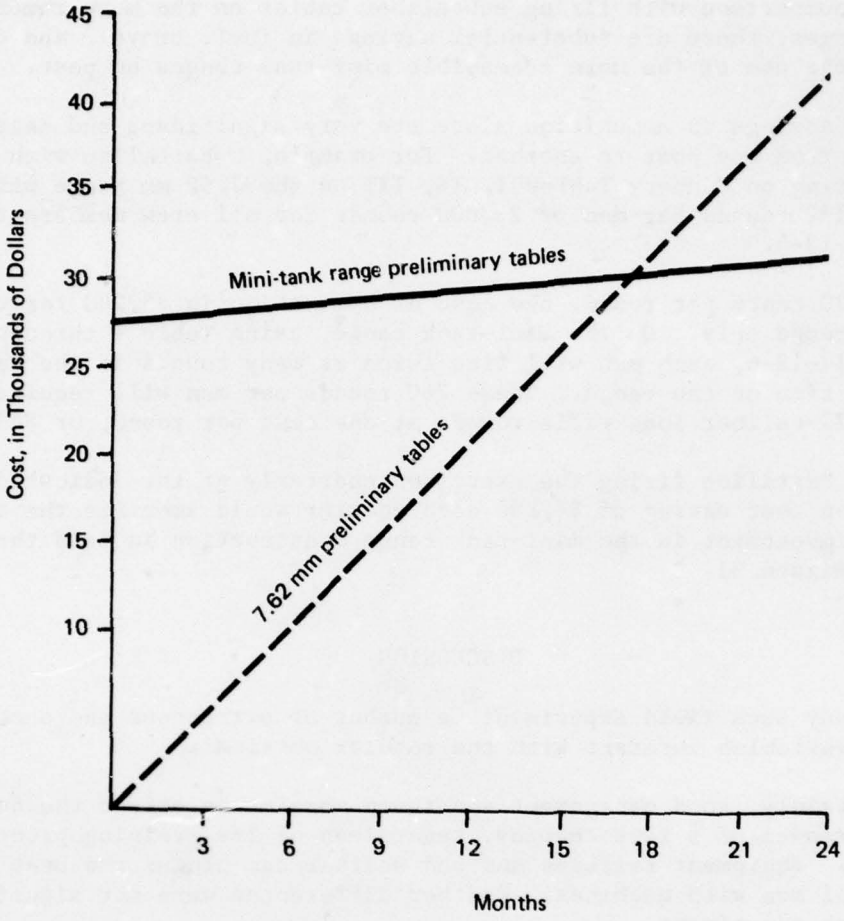

Figure 3. Accumulated cost of rounds fired by a battalion in quarterly exercises on the preliminary tables. *(Capital investment in mini-tank range at $27,600; capital investment in 7.62 mm range assumed zero.)*

In the analysis of the data gathered in the experiment, the data on performance time and hits from the sequential tables were plotted and examined for the regular increases characteristic of learning curves. Any such regular improvement within tables was largely obscured by variations in target, range, and ammunition requirements occurring in a near-random fashion throughout.

Regular increases between gunnery tables, more representative of learning increments, were noted (Tables 5, 6, and 8).

Early in planning, it was thought that the gunners' prior experience might show a relationship with Gunnery Table VIII scores. The three groups differed somewhat in time in MOS and time in gunner assignment (Table 1).

However, correlation coefficients between MOS experience and Table VIII scores as well as between gunner experience and Table VIII scores were not significantly different from zero. It was reasonable to expect positive relationships among performances on different tables.

However, all correlation coefficients among Table II mini-tank range and Tables IV, V, and VIII main gun performances were insignificant. Nevertheless, it may be possible to structure the results of gunnery exericses so as to improve the prediction of gunner success.

The possibility of improving the prediction of gunner success is explored further in Appendix B.

Given the prevalence of null relationships among gunnery exercises and experience indicators, it is perhaps the more surprising to observe differences among the groups. There were, of course, differences between the experimental groups and the control group in their preliminary table experiences. These differences argue for the greater efficiency of the mini-tank range exercises. Both experimental groups were able to set up and zero their weapons more efficiently and the X_2 group was able to fire twice as many rounds as the control group in the same time on the range and at less cost.

The major question addressed was that of transfer of training from mini-tank range exercises to main gun performance. Main gun performance differences between groups were small and generally not statistically significant. However, the differences were considered important from a military viewpoint.

The X_2 group, which followed the TC 17-12-6 procedures and fired the full 260 rounds on Tables I through VII (mini-tank range), showed the best time and hit performance on main gun Table IV and achieved the best overall performance on Gunnery Table VIII with no crew failures.

The median performance of the X_2 group was Distinguished. The median performances of the X_1 group and of the C group were at the Expert level with 5 failures and 2 failures, respectively.

CONCLUSIONS

The mini-tank range exercises were in general more accurate, efficient, and less costly than the 7.62 mm range firing used for comparison.

Use of the mini-tank range exercises in preliminary subcaliber training prior to main gun firing was shown to be at least equally effective in terms of training transfer.

Gunners given the full training experience (260 rounds) on Gunnery Tables I through VII (TC 17-12-6) performed well on main gun Tables IV and VIII. Cutting these preliminary exercises 50% (130 rounds) resulted in a relatively poor performance on main gun tables.

The favorable training effect of the mini-tank range exercises may be further enhanced by better scoring, practice distribution and administration of the exercises with emphasis upon correct crew procedures (Appendix A).

The evidence here is limited to the use of mini-tank range training in preliminary exercises or supplementary exercises. The evidence obtained does not show the effect of substitution of mini-tank exercises for main gun tables; all three groups fired a full allotment of main gun rounds on Tables IV, V, VII and VIII.

APPENDIXES

APPENDIX A SUGGESTIONS FOR IMPROVED MINI-TANK RANGE EFFECTIVENESS

There were some problems in the administration of the mini-tank range training and in the procedures and scoring given in TC 17-12-6, which provided guidance on operation of the mini-tank range.

The following suggestions for improving training are not research conclusions per se, but are based on field observations and general training research background.

With regard to the TC 17-12-6, two suggestions for improvement emerged from the experience with this training.

First, the scoring patterns recommended are inaccurate and inconsistent and should be corrected and properly explained.

Second, only one of the first seven Gunnery tables, Table VII, includes moving targets. These moving target exercises appeared both enjoyable and beneficial to the crew members, perhaps partly as a diversion from the tedium of a long series of stationary target exercises. The inclusion of additional moving target engagements, spread through some of the earlier exercises, may be beneficial, and just as important, may add considerable interest to the other tables.

With regard to the administration of the mini-tank range exercises, the following obervations may be helpful.

The common practice of guiding each man through the seven mini-tank range tables in one continuous session contributed to the monotony of the exercises. Better training results usually can be obtained by distributing such repetitive practice over several sessions, permitting any one crewman a greater variety of activities within the training day. In this instance, distributed practice should present no appreciable added costs in training time or inconvenience. It may prove more efficient to present the mini-tank range training in several phases, e.g., Gunnery Tables I II, and III; Tables IV, V, and VI; and Tables VII and VIII.

In the conduct of the Tank Crew Qualification Course (TCQC) an assistant instructor (AI) rode on each tank. In the conduct of the mini-tank range training, an officer or noncommissioned officer often served as AI on the tank, sometimes serving as observer or as loader, while directing the sequence of training. (See Figure 1.) Observations indicate that such an AI can be of great value to the crew in training, providing feedback to the gunner, checking procedures of the tank commander, loader, and gunner, and observing for correct safety practices. The AI can make the crew training not only more effective but can also benefit from an objective review of another crew. For this reason, a tank commander or gunner from another tank crew can both give and receive training benefits as an AI. It may be obvious that the same observations apply to the main gun tables also, where an AI on each tank on the line can be extremely valuable in improving training and maintaining safety.

Greater efficiency in operation of a complex system such as the mini-tank range can be achieved by providing training for the trainers who will be responsible for supervising the set-up and assisting in the conduct of the training.

On the main gun ranges, Tables IV and V, the following recommendations are pertinent. The use of an AI on each firing tank monitoring time-to-fire, crew procedures, and safety practices, could have great training benefits. As indicated above, these AIs can be selected from among tank crews not on the firing line, and can be expected to benefit from the active participation in the training while improving safety practices and firing procedures among the crew.

These AIs could be placed and supervised by a designated non-commissioned officer who might also provide control of ammunition and traffic flow and ground liaison between the control tower and various points on the range. Such a designated range NCO could resolve many frustrating situations for which communications between the tower and range points are otherwise inadequate.

APPENDIX B. PREDICTION OF GUNNER PERFORMANCE

For the purpose of assigning the most promising trainers to the gunner position within crews, it is important for the commander to know early in training which crew member is likely to become a successful gunner. Each firing table, whether it be a mini-tank range table or a main gun table, can be regarded as a work sample of the qualification table, Table VIII, because each prior table includes some important training toward the later qualification. Unfortunately, the product-moment correlation coefficients calculated to show relationships among the gunnery tables recorded in the present study were, in general, null. The attempt to predict Table VIII scores from Table II mini-tank range scores was not successful either. Scores were not recorded on mini-tank range tables given after II; additional data currently in process of collection will include other such tables and may give better prediction.

Even main gun Tables IV and V showed no significant positive relationship. Table V did not predict Table VIII. The prediction of Table VIII from Table IV (main gun) was more successful (r_b = +0.51, $p \leq 0.01$) after arrangement into a dichotomous table (qualified vs. non-qualified) (Table B-1).

The column headed CUTOFF on Table B-1 indicates the percentage of gunners who qualified on Table VIII after achieving a given cutoff on Table IV. Selection of 41% hits on Table IV as cutoff would have produced a 94% probability of success on Table VIII. A more practical compromise, assuming a limited trainee population and a high demand for gunners, might be a cutoff at 31% hits on Table IV, above which 87% of gunners qualified. Below this cutoff only 9 out of 35 (26%) of potentially qualified gunners were eliminated, and the probability of success in the group below this level was a rather consistent 50%.

Table B-2 expands the same data shown in Table B-1 to indicate clearly which gunners were changed (C) prior to Table VIII firing, which fired and did not qualify (N), and which qualified minimally (Q), at Expert (E) level, and at Distinguished (D) level.

This table shows that the company commanders did eliminate some poor performers on Table IV, but they were influenced also by other considerations. Indeed, some of the poor performers on Table IV did very well on Table VIII.

However, it is possible that the Table VIII qualifications could have been increased by 10% to 20% by using an arbitrary cutoff at a level near 31% hits on Table IV.

Given the poor relationships found within and among gunnery tables in this research, conclusions about relationships among gunnery tables must be regarded as tentative until additional data are obtained. Research exploring a variety of discriminators of armor crewman success is continuing within the Army Research Institute.

Table B-1

PREDICTION OF QUALIFICATION ON TABLE VIII FROM TABLE IV

Table IV % Hits	Table VIII N[a]	Q	Cutoff %Q
91-100	0	0	0
81-90	0	1	100
71-80	0	0	100
61-70	0	2	100
51-60	0	4	100
41-50	1	9	94
31-40	3	10	87
21-30	6	5	76
11-20	3	3	72
0-10	1	1	71
TOTALS	14	35	n = 49 r_b = +0.51 significant at p< 0.01

[a] Includes personnel not qualified and those changed from gunner position prior to Table VIII.

Table B-2

DETAILED PREDICTION OF QUALIFICATION ON TABLE VIII FROM TABLE IV

Table IV % Hits	Table VIII Performance: Not Qualified C	Not Qualified N	Qualified Q	Qualified E	Qualified D	Cutoff % Qualified
91-100						
81-90				1		100
71-80						100
61-70			1		1	100
51-60			2		2	100
41-50		1	2	1	6	94
31-40	2	1	1	2	7	87
21-30	4	2	1	2	2	76
11-20	2	1	1		2	72
0-10		1			1	71
	8	6	8	6	21	n = 49

APPENDIX C SUMMARY TABLES FOR ANALYSIS OF VARIANCE

ANOVA on Time-to-Fire First Round Each Engagement (Table 5 in text.) Groups C, X_1, and X_2 with Gunnery Tables IV and V.

Summary Table

Source	SS	df	MS	F	p
Between subjects	465.29	44			
A (groups)	100.35	2	50.17	5.78	.01
Subjects within groups	364.94	42	8.68		
Within subjects	332.00	45			
B (tables)	48.39	1	48.39	10.50	.005
AB	89.85	2	44.92	9.74	.001
B x subjects within groups	193.76	42	4.61		
TOTALS	797.29	89			

Summary Table for Simple Effects

Source	SS	df	MS	F	p
Between subjects					
Groups with Table IV	158.97	2	79.48	11.95	.001
Groups with Table V	31.24	2	15.62	2.34	—
Within cell	558.70	84	6.65		
Within subjects					
Tables with C	136.53	1	136.53	29.62	.001
Tables with X_1	1.20	1	1.20	.26	—
Tables with X_2	.53	1	.53	.11	—
Tables x subject within groups	193.76	42	4.61		

ANOVA on percent engagements meeting time criteria (Table 5 in text.) Groups C, X_1, and X_2 with Gunnery Tables IV and V. Same ANOVA was also applied to arc sine transformations of percent scores with similar results; between groups significant at $p < .01$ and interaction significant at $p < .01$.

Summary Table

Source	SS	df	MS	F	p
Between subjects	21,228.72	44			
A (groups)	3,836.15	2	1,918.08	4.63	.05
Subjects within groups	17,392.57	42	414.11		
Within subjects	12,964.00	45			
B (tables)	688.90	1	688.90	3.42	—
AB	3,818.87	2	1,909.44	9.48	.001
B x subjects within groups	8,456.23	42	201.34		
TOTALS	34,192.72	89			

Summary Table for Simple Effects

Source	SS	df	MS	F	p
Between subjects					
Groups with Table IV	7,290.18	2	3,645.09	11.85	.001
Groups with Table V	364.84	2	182.42		
Within cell	25,848.80	84	307.72		
Within subjects					
Tables with C	3,898.80	1	3,898.80	19.36	.001
Tables with X_1	45.63	1	45.63		
Tables with X_2	563.33	1	563.33		
Tables x subject within groups	8,456.23	42	201.34		

ANOVA on hit percent for gunners (Table 6 in text). Groups C, X_1 and X_2 with gunnery table IV and V.

Summary Table

Source	SS	df	MS	F	p
A (groups)	237.43	2	118.72	.46	—
Subjects within groups	11,941.09	46	259.59		
B (tables)	9,825.52	1	9,825.52	27.21	.001
AB	1,905.76	2	952.88	2.64	—
B x subjects within groups	16,609.52	46	361.08		

ANOVA on score calculated as percent of maximum score possible (Table 7 in text). Groups C, X_1 and X_2 with gunnery Table VIII.

Summary Table

Source	SS	df	MS	F	p
Between groups	1,109.91	2	554.95	2.02	—
Within groups	10,435.21	38	274.61	—	—
TOTALS	11,545.12	40			

ANOVA on percent of engagements in which at least one hit was scored (Table 8 in text). Groups C, X_1 and X^2 on gunnery tables IV, V and VIII.

Summary Table

Source	SS	df	MS	F	p
A (groups)	387.93	2	193.97	.52	—
Subjects within groups	14,292.51	38	376.12		
B (tables)	12,057.32	2	6,028.66	19.40	.001
AB	118.24	4	29.56	.10	—
B x subjects within groups	23,614.81	76	310.72		

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